

How the traditional method of building construction has become seriously flawed in terms of delivering a well-functioning building to an owner

Building Commissioning: Benefits and Costs

By PAUL C. TSENG, PE, CEM,
*Chief of Facilities Engineering
 and Management Services,
 Dept. of Public Works and
 Transportation,
 Montgomery County,
 Rockville, Md.*

Building commissioning is being increasingly recognized by owners as an effective means of reducing costs and ensuring quality as well as performance in building systems. Building owners are demanding higher performance in their buildings from their engineers, architects, and contractors. Smart owners and discerning engineers recognize that price and quality are two sides of the same coin in a building process.

The plan-spec-bid-build process-typical in most public, institutional, and private sector projects-is seriously flawed. The growth of the building commissioning movement is a long overdue effort to infuse quality into this flawed process.

The conventional plan-spec-bid process diffuses responsibility, muddies the performance measures, and does not allow for an integrated process for the delivery of the final product-a functioning, high performing building. The three main players-the owner, the design team, and the contractor team-are engaged in a triangular relationship that is contractually and inherently unstable. This relationship is also confronta-

tional by its nature, blame-shifting by its practice, and actually rewards poor performance (Table 1). Unfortunately, this conventional process is widely used by government, institutional, and many pri-

vate sector owners.

The traditional process promotes finger-pointing, generates expensive change orders, and leads to high litigation costs. This model systematically sacrifices quality in

TABLE 1—Conflicting expectations in building process.

Owner's expectations	A/E expectations	Contractor expectations
A/E delivers design that meets owner's use requirement.	Masterpiece gets built without changes.	Build project and move on to next project.
A/E delivers design that's maintainable.	Paid for basic services in a timely manner.	Plans and specs are clear, concise, and error-free.
A/E supervises the construction.	Additional compensation for non-basic services.	Build what is on the plans and specs without being responsible for building performance or evaluating design.
A/E will tell owner of construction defects.	Does not want to supervise construction.	Want the owner and NE to be responsible and expect the impossible.
Contractor to build/work in a workmanlike manner in accordance with general accepted construction practices.	Does not want to deal with change orders.	Paid in a timely fashion.
Contractor to build work with good quality material free from defects.	Does not want to deal with owner/contractor disagreements.	No delays or provide compensation for delays.
Contractor to build work for agreed-to price.	Doesn't want to address RFI's from job site.	Time and money allowed for extras.
Contractor to build work on schedule.		
Contractor to pay his subcontractors and suppliers in a timely fashion without liens.		

Source: Carl N. Lawson, Richard Tyler, Esq.

TABLE 2—Traditional factors supporting the need for a building commissioning program.

- ▲ Unclear design intent
 - A Complex building systems
 - A Unclear standards and criteria for gauging system
- ▲ Lack of functional performance testing
 - A Conflicts between drawings/specifications and applicable codes
 - A Inadequate system documentation
 - A Maintainability and equipment accessibility problems
 - A Inadequate provision for maintenance
- ▲ Inadequate O&M manuals
 - A Inadequate training of O&M staff
 - A Numerous change orders and cost overruns

Source: GSA Building Commissioning Guide, 1997.

TABLE 3—Top 10 deficiencies discovered by commissioning new and existing buildings.

- ▲ Incorrect scheduling of HVAC and lighting equipment.
- ▲ Incorrect cooling and heating sequences of operation.
- ▲ Incorrect calibration of sensors and instrumentation.
- ▲ Lack of control strategies for optimum comfort and efficient operation.
- ▲ Malfunctioning air and water-side economizers.
- ▲ Under-utilized computer-based control systems.
- ▲ Short cycling of HVAC equipment leading to premature failure.
- ▲ Lack of design intent and building documentation.
- ▲ Lack of training for building operators or service contractors on complex systems.
- ▲ Missing specified and paid-for equipment.

Source: Portland Energy Conservation, Inc.

the name of the lowest price. This in turn discourages creativity and innovation in the name of risk management. It also stifles teamwork among the principal players in the name of schedule control.

Other factors making commissioning of buildings necessary are shown in Table 2.

1998—A reality check

The building industry is currently enjoying a robust rebound after years of downturns. While the design consultants are once more busy designing new buildings or renovating old ones, the costs to owners continue to climb as building systems get ever more complex and regulatory requirements ever more stringent. In the 1990s, the technologies used in buildings have made significant advances, particularly in the computer-based technologies.

The reality to building owners is the fact that there is a pervasive absence of quality in the finished product. To a vast majority of owners, buildings are not performing as expected. An astonishing number of their projects are woefully under-performing. Substantial completion on many projects is



The owner's commissioning engineer has verified that the vibration isolators between the air-cooled chiller and concrete pad have been properly installed.

merely the start of a lengthy shutdown period for a myriad of building system problems that often can take a year or longer to sort out the bugs and defects.

Owners who think they have already paid for and are getting quality are engaging in self-denial. Exercises in cost-cutting, value engineering, and down scoping invariably affect the quality of a project. In far too many projects, cutting out quality has been the business norm, not the exception.



The 29,000 sq ft East County Community Recreation Center, Montgomery County, MD. View is of the gymnasium side.

Sadly, only a tiny minority of buildings are designed and constructed with such attributes: quality, innovation, and teamwork that are exhibited by other sector: in our economy that excel in high performance (Table 3).

Forces for change

● **Dissatisfaction with building performance**—For a vast majority of building owners and facility managers, the functional performance of their building systems are simply not meeting their expectations. A study of 60 commercial buildings for which the results were presented at the 1994 National Conference on Building Commissioning, sponsored by Portland Energy Conservation, Inc., found that:

*More than half of the buildings suffered from control problems.

- 40 percent have HVAC equipment, problems.

- 25 percent had energy management control systems (EMCS), economizers, and/or variable speed drives (VSDs) that did not run properly.

- **Owner demand and expectation** The building owners and operators are no longer content with poorly designed and non-performing buildings. Marginal performance directly translates to the bottom line costs for building owners. In the era of downsizing and budget cuts, they can no longer afford or ignore costly fixes. If design engineers continue to fail in meeting owners' expectations, they will **become** irrelevant in the market place.

- **Litigation** Building defects and malfunctioning HVAC systems have led to numerous lawsuits by building owners. In fact, litigation and liability concerns often influence design decisions and construction methods. Litigation never improves a building's performance or its quality; it merely drains the coffers of all parties involved.

BC defined: A process

Building commissioning is making positive changes to the process of creating buildings. Achieving those changes does not happen by accident. It is by deliberate efforts of the entire team. Commissioning requires that design engineers get closer to their customers. Engineers need to **recognize** that it is the end users and building owners they must seek to serve, not the architects.

For commissioning to be successful in practice, it must be viewed as a process. It is not merely an **exercise** before a building is turned over to its owner. The traditional walk-through garden variety turnover process is simply inadequate. It does not ensure the proper installation and smooth operation of numerous building subsystems, me-

chanical or otherwise, that go into a modern building of any size. It is important to recognize that for any process to add value, it must have substance and content. The commissioning process must be carefully tailored to provide both. A systematic and detailed process that embraces and expands on ASHRAE's "Guideline for Commissioning of HVAC Systems," 1989 is required to achieve the desired result effectively-a building properly constructed with all its systems performing as designed.

The best definition for building commissioning is summarized below:

- Commissioning is a systematic process-beginning in the design phase, lasting at least one year after construction, and including the preparation of operating staff-of ensuring, through documented verification, that all building systems perform interactively according to the documented design intent and owner's operational needs.

Commissioning, therefore, requires that design engineers, architects, and contractors go beyond what is traditionally practiced in construction quality assurance and building turnover. In effect, it requires a new framework and a mindset on the part of all participants in the design/construction process. This would require the owner, project architect and engineers, contractor, and all major sub-contractors to work as a team and focus on delivering a quality end product-a high performance and high quality building. A model commissioning process is shown in Fig. 1.

Commissioning benefits

It seems everyone involved in the construction process is in a big hurry while holding tightly to their wallets. The principal players have lost their sense of purpose in their respective efforts, which is to deliver to their customer-the owner-a productive, healthy **work** environment that

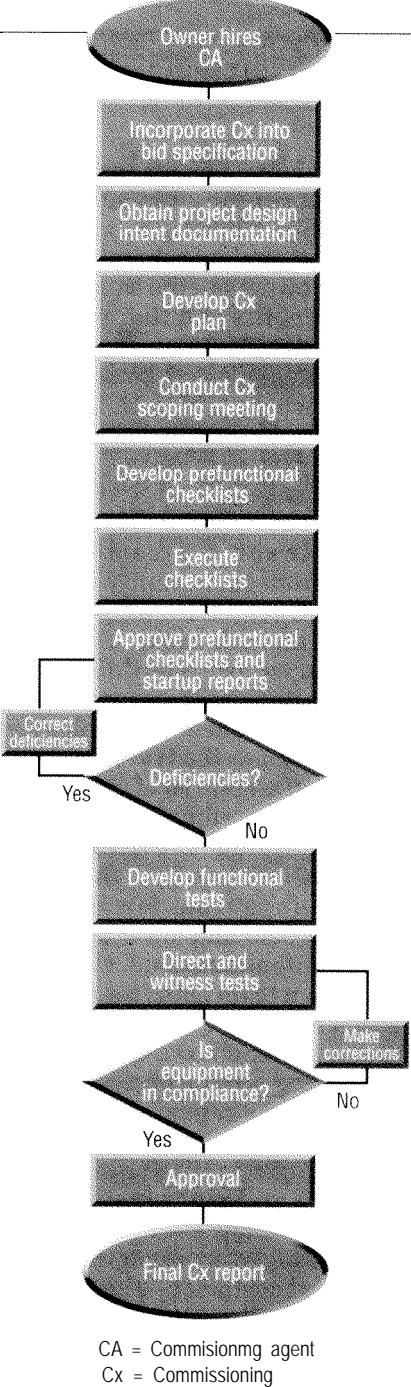


Fig. 1 A typical commissioning process.

enhances value to their employees or tenants.

- Inspection is not enough to ensure quality in buildings. Control measures must be integrated and interwoven throughout the entire delivery process from the project program through design, construction, and turnover. A high performance **car** cannot be manufactured if we simply engage in rejecting and unacceptable product. The **car** maker must develop a

quality control process that makes a smooth running car an achievable reality. Building commissioning is the quality control tool for building owners to the same end.

The benefits of a thorough and rigorous commissioning process are self-evident and not just only for the owners (Table 4). Contractors and subcontractors know that on those jobs with commissioning requirements, it is not advisable for them to cut corners. Contractors and their sub-contractors also benefit from their ability to lower their cash set-asides for warranty reserves and call-backs. The architects can expect a building with far smaller post-construction headaches for them to handle. The engineers know the HVAC systems are virtually assured of working as intended, thus eliminating post-occupancy troubleshooting visits. The owners know that the promised savings from fewer costly change orders and lower operating and maintenance costs will occur. The design team gains the prospect of repeat and expanded business from a satisfied owner. The time wasted and cost incurred in litigation or claims can be channeled to more productive endeavors.

Building commissioning, when properly and rigorously implemented, makes everyone a winner. The biggest winner, however, is the real customer-the building occupants. For them, there are two very noticeable benefits:

- **Increased productivity**—Owners, design engineers, and architects must first redefine what a

building is to them. Is a building and its systems simply to be a utility closet, a Taj Mahal, or a showcase of engineering marvel? Commissioning pioneers, such as Dr. Charles Dorgan of HVAC&R Center in Wisconsin, have been pressing owners to realize that buildings are “productivity engines.” A poorly performing building and its systems directly impact the “bottom line” and the “mission” for which the building was built in the first place.

By redefining buildings as “productivity engines” in which value is added, net profit is generated, and unnecessary costs avoided, owners will come to view quality in a very different light. A higher performing building with a smooth functioning HVAC system produces a higher level of productivity by its occupants. This fact is especially important in today’s concern over indoor air quality.

A healthy building with quality HVAC and lighting systems conveys caring by a company to its employees. It garners greater loyalty, reduces distraction and complaints, reduces time lost due to environmental irritants, and enhances creativity. When an owners and designer are willing to cut corners, they will eventually compromise the purpose of the building.

- **A paradigm shift back to quality**—For too long, owners, designers, and contractors have devised a process in which the sched-

ule and cost are the end games. In fact, on most projects, these two outcomes are the only basis for monetary incentives. Building commissioning introduces a fundamental paradigm shift from the price/schedule dimension to a quality-focused dimension.

To building owners, the bottom line cost savings can be dramatic.

TABLE 5—Cost savings from building commissioning.

- A Energy savings of 20 to 50 percent (\$0.50 to \$1.25 per sq ft saved).¹
- A Maintenance savings of 15 to 35 percent (\$0.50 to \$1.25 per sq ft).
- A Reduce claims of 2 to 10 percent in inverse of project size.
- A Confident of a “job well done” by eliminating in-house overtime costs.
- A Properly functioning equipment by reducing trouble-shooting costs.

¹Based on BOMA reference cost data for office buildings

TABLE 6—Building commissioning outcomes

- ▲ Energy efficiency
- ▲ Healthy indoor air quality
- ▲ Optimized functional performance
- ▲ Maintainability
- ▲ Constructibility

Savings in energy costs can be between 20 to 50 percent. Maintenance and operational savings can be between 15 to 35 percent. Table 5 shows these savings for a typical owner.

Commissioning components

There are many and varied elements in building commissioning. The five major components are:

- Clarification of owner priorities and design intent.
- Thorough documentation and monitoring of all facets of construction.
- Extensive testing of all sub-systems and their components and controls.
- Specific and detailed training on each major equipment for operational personnel.
- On-going monitoring and warranty services of major equipment.

To implement a commissioning process properly, a prioritized set of clear goals or outcomes must be articulated by the owner, Table 6 offers suggested core goals or outcomes.

The issue of “constructibility” has generally been neglected by most commissioning practitioners. While some construction managers claim to cover this issue, few genuine interdisciplinary reviews are actually performed by either the design team or the contractors. It is necessary to have, as part of

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TABLE 4—Benefits of commissioning for owners.

- ▲ Reduce change orders and claims.
- ▲ Reduce project delays.
- ▲ Enforce start-up requirements.
- ▲ Shorten building turnover period.
- ▲ Reduce post-occupancy corrective work.
- ▲ Minimize effects of design defects.
- ▲ Improve productivity and indoor environment.
- A Increase maintainability and reliability.
- ▲ Reduce energy and operating costs.
- A Increase value by better quality construction.

the commissioning program, a basic goal of constructibility. In other words, one must ask the simple question, "Can this project be built as designed?" so that countless problems can be avoided as construction gets underway. For example, in too many instances, owners have been forced to pay for field changes simply to allow HVAC equipment to fit into a mechanical room that was designed too small to accommodate it.

TABLE 7—What needs commissioning.

- ▲ HVAC system
- ▲ Building controls system
- ▲ Smoke control system
- ▲ Life safety systems
- ▲ Lighting system and controls
- ▲ Thermal envelope systems
- ▲ Specialty equipment
- ▲ Roofing system

portant at the outset that the owner be actively engaged and firmly establish expectations and requirements for the team. A suggested team composition is shown in Table 8. The following are some suggestions for each participant:

The owner—The owner must be actively involved and not simply the one who pays the bills. The specific functions should include: defining requirements and assigning commissioning responsibilities for the architect/engineer team; assigning a designated project manager to be the point of contact for the commissioning authority; assigning maintenance personnel and involving them in various commissioning meetings, training sessions, and inspections; defining the scope and tasks for the commis-

TABLE 8—The commissioning team.

Owner	General contractor
Commissioning authority	Mechanical & electrical subcontractor
Architect	Test and balance specialist
Engineer of record	Energy management system specialist

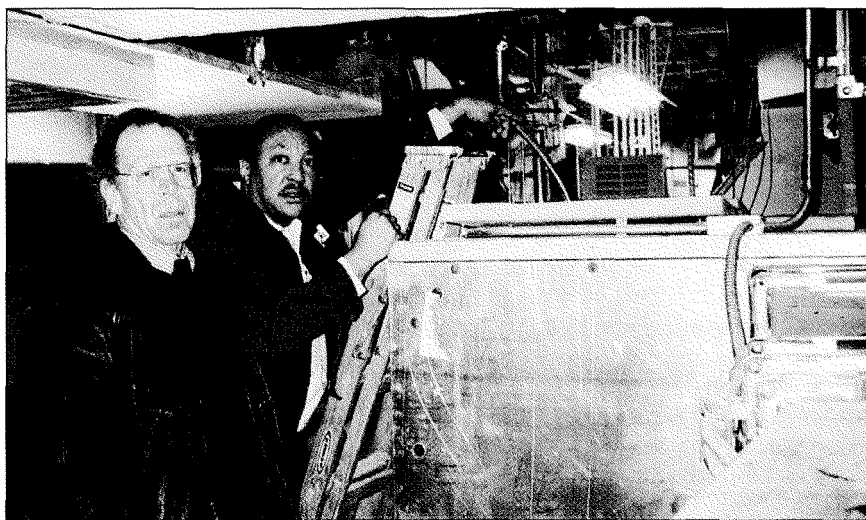
sioning process. Special focus should be on maintainability and accessibility and scheduling and conducting all pertinent commissioning activities. These include pre-commissioning activities, training sessions, walk-through inspections, review of operations manuals, testing and balancing, and demonstration of system operations.

The architect—The project architect should ensure that the shop drawing submittal reviews are coordinated with the commissioning authority.

Engineer of record—The engineer has a pivotal role in the commissioning process. The owner must ensure that the engineer include commissioning activities in the fee proposal so that the engineer can take an active part in the process.

The engineer needs to perform the following tasks: document design intent, including design narratives in Section 15010—"Mechanical General Provisions" and Section 16010—"Electrical General Provisions;" coordinate O&M manual requirements in Section 15995—"Commissioning of HVAC System" and Section 16995—"Commissioning of Electrical Systems." He must also conduct HVAC training sessions on the system design overview; design intent and equipment selection; prepare as-built drawings and submit them to the commissioning authority; and review shop drawings and submittals for maintenance access and specification compliance.

General contractor—The contractor must include the cost for commissioning requirements in the bid price and ensure that such requirements in the mechanical and electrical subcontracts, among others, are complied with. The con-



Commissioning requires the active involvement of an owner's staff. Here, the lead HVAC mechanic is pointing out an installation problem to the commissioning engineer.

Table 7 depicts the scope for building commissioning.

Roles and responsibilities

There are many participants in the commissioning process. Regardless of the functional organization of the commissioning team, their roles and responsibilities need to be clearly defined. It is im-

portant to develop commissioning authority; and developing enforceable contractual provisions sufficiently strong to assure compliance by contractor.

The commissioning authority—Depending on the preference of the owner, the designated commissioning authority should have specific duties, including reviewing the plans and specifications with

tractor must also ensure full cooperation of all subs in the process.

Mechanical subcontractor. Likewise, the subcontractor must also include commissioning requirements in the contract price. Furthermore, the mechanical subcontractor must coordinate the project schedule to ensure participation of specialty subcontractors such as sheetmetal and pipe fitters, test and balance, water treatment and refrigeration subcontractors. An important function for them is to include participation of major equipment manufacturers and their representatives. Attendance at all commissioning activities scheduled by the commissioning authority is a must.

Other duties of the mechanical subcontractor include: coordinating all testing with pertinent specialty subcontractors; conducting walk-through inspections and hands-on training with equipment vendors and other subcontractors; providing certification of system performance and demonstrating functional performance of each piece of major equipment to the commissioning authority; and turning over a complete set of as-built mark-up drawings to the design engineer for his final incorporation into as-built drawings.

Electrical subcontractor. The electrical subcontractor should have functions and duties similar to those of the main mechanical subcontractor. In fact, close coordination of these two main trades is crucial for the success of the commissioning process.

Test and balancing (TAB) contractor. The TAB specialty contractor is frequently the last one to get involved in the construction process. Yet, it must be realized that proper com-

missioning of HVAC systems cannot be accomplished without him. The owner should insist that the TAB contractor is fully qualified to be involved during the commissioning planning. The specific role of the TAB specialty contractor should include: conducting TAB work and demonstrating to the commissioning authority the performance of the equipment covered under "Verification of Performance" in Section 15995 — "Commissioning of HVAC System;" and participating in training sessions.

Energy management system contractor. A properly installed and debugged energy management system is essential for HVAC system commissioning to succeed. Data trend and diagnostic capabilities of a digital control system are invaluable during commissioning. A properly designed trend log by the EMS contractor can significantly reduce time required for functional performance testing of the HVAC components.

Owners may want to further delineate responsibilities for the project participants. Depending on the chosen form of project delivery, such as design-build, re-



Commissioning team members included (left to right) the project architect, HVAC contractor's foreman, and the project engineer.

sponsibilities can be assigned as shown in Table 9.

Commissioning options

Who does the commissioning? - The first obvious option is for the owner to be the commissioning authority. Since the in-house staff frequently write the commissioning program and requirements, it seems advantageous to take control of the commissioning process to ensure the contractor delivers the building properly. The disadvantages are the lack of additional staff resources to be dedi-

cated to the effort and a potential risk of delay claims by the contractor as a result, especially true if there were disputes involved with respect to the completeness of design and the satisfactory performance of system components.

An independent commissioning authority is the second option that permits the owner to obtain an outside expert to serve as the watchdog and the orchestrator of the commissioning process. The expert can report directly to the owner on the performance of the contrac-

TABLE 9—Recommended responsibilities for HVAC.

Task	Design bid build	Design/build
Concept design	DC	CDC/CTR
Sizing services	DC	CDC/CTR
Budget estimates	DC	CTR
Life cycle estimates	DC	CDC
Schematics	DC/CC	CDC
Design development	DC/CC	CDC
Construction documents	DC/CC	CTR
Bidding	DC/CTR	CTR
Automation/controls	DC/CC/CTR	CDC/CTR
Site Inspection	DC	CDC
Punch List	DC	CDC
Commissioning	CC	CDC
Warranty	CTR	CTR
Monitoring	DC	CDC
GTR = Contractor CC = Commission consultant DC = Design consultant CDC = Combined commissioning and design consultant		

tors and provide planning and scheduling as well as monitoring of the commissioning progress. The disadvantage is that the outside consultants are not in a good position organizationally to coordinate subcontractors for the innumerable commissioning activities. The line of authority needs to be clearly defined if this option is used by the owner.

The engineer of record for the project can serve as the commissioning authority. There are many benefits in using the design engineer in the capacity of the commissioning authority because the engineer has full knowledge of the system design and, therefore, is intimately familiar with its intended sequences of operation. It is often logical to retain the engineer to serve the interests of the owner in this capacity. The integrity of the process, however, might not be well served if the design has serious flaws or omissions. Conflicts with contractors may also impede the commissioning activities.

The general contractor (GC) frequently can serve effectively as the commissioning authority and will frequently need to hire an engineer with appropriate experience for this purpose. Because the GC has a stake in the successful completion and timely delivery of the entire project, he generally has the desire to ensure that the building systems, especially the HVAC, fire protection, and electrical systems, can pass muster. There is also the financial benefit directed to the GC's bottom line since he normally can reduce the warranty reserves significantly and reduce the unnecessary in-warranty service calls. A commissioning authority under the GC has added authority to coordinate subcontractors for commissioning activities. The drawbacks are that it gives the appearance of a conflict of interest. The question confronting the owner is whether a GC can be relied upon to do a credible job for the owner, especially if the construction is behind schedule and a significant liquidated dam-

Commissioning resources

The following commissioning resources provide more detailed information on building commissioning.

■ **"Montgomery County Government-Contractor Quality Control and Commissioning Program-Guidelines and Specifications,"** Div. of Facilities and Services, December 1993. To order, call Paul Tseng at 301-217-6000. Price: \$45 per hard copy, \$55 per diskette.

■ **"Model Commissioning Plan and Guide Specifications,"** prepared by Portland Energy Conservation, Inc., for U.S. DOW Region 10, 1996. To order an electronic version, call NIST at 1-800-553-6847.

■ **"Guideline For Commissioning of HVAC Systems,"** ISSN, 1049-894X, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta, Ga., 1989.

The ***Building Commissioning Handbook***, J. Heinz and R. Casault, Association of Higher Education Facilities Officers, Alexandria, Va., 1996. To order write APPA, The Association of Higher Education Facilities Officers, 1643 Prince St., Alexandria, VA 22314.

■ **"Commissioning Toolkit,"** published by the Oregon Dept. of Energy and prepared by Portland Energy Conservation, 1997. To order call 503-378-4040 (within Oregon, call 1-800-221-8035).

■ **"Commissioning: A New Way to Ensure Value in the Construction Industry,"** C. N. Lawson, *TAB Journal*, Fall 1997.

■ **"Commissioning the Physics/Astronomy Building Control System,"** Bonneville Power Administration, Portland, Ore., 1996, written by Phoebe Caner, University of Washington. To order, call 503-230-7334.

■ **"Commissioning for Better Buildings,"** Florida Power & Light, Miami, Fla., 1996, prepared by Portland Energy Conservation, Inc. To order, call 1-800-FPL-5566. Charges may apply.

■ **"Building Commissioning Guidelines, Second Edition,"** Bonneville Power Administration, Portland, Ore., 1992, prepared by Portland Energy Conservation, Inc. To order, call 503-230-7334.

■ ***Commissioning Manual for Mechanical Systems in Federal Buildings***, U.S. Dept. of Commerce, National Institute of Standards and Technology, Gaithersburg, Md.

■ **"Engineering and Design Systems Commissioning Procedures,"** U.S. Army Corps of Engineers, Washington, D.C., 1995. To order write: Dept. of the Army, U.S. Army Corps of Engineers, Washington, DC 20314. Refer to ER 1110-345-723.

■ **"Proceedings of the National Conferences on Building Commissioning,"** 1993-1996, Portland Energy Conservation, Inc. Portland, Ore., Portland Energy Conservation, Inc., 1993. To order, call 503-248-4636. Charges apply.

■ ***HVAC Functional Inspection and Testing Guide***, NISTIR 4758, U.S. Dept. of Commerce, National Institute of Standards and Technology, prepared for the General Services Administration by J. Y. Km, March 1992.

age is involved for delays.

The last option is to use the principal mechanical and electrical subcontractors whose trades account for the bulk of the commissioning requirements on most projects. The advantages are that the installers can carry out the requirements as part of the system check-outs and start-up functions.

Both the mechanical and elec-

trical subs also have a stake in the successful completion of the project, especially since they carry the most burden in terms of in-warranty service responsibilities in the event of failures. Often, the energy management system contractor and the testing and balancing specialist can jointly perform the functional performance tests as part of the

commissioning activities.

The shortcoming of the subcontractors is that they frequently do not have the in-house engineering expertise to commission the systems they installed. The owner, in using this option, must also ensure that the subs actually have the capability to perform the various testing, balancing, and performance verification tasks involved in the commissioning of the HVAC and electrical systems. The final drawback is that frequently the mechanical and electrical subs simply will **never** admit their own problems and mistakes. This factor may preclude this option to be **viable** in practice.

A preferred option by many owners who have been involved with commissioning is to engage directly or pre-qualify a selected number of independent commissioning experts. This stable of experts can then be retained for a specific project or recommended to the GC or construction managers. Of paramount importance is for the owner to delineate the organizational roles and responsibilities clearly for the commissioning authority that works for them. As an example, for public sector owners, commissioning may be more easily implemented by the general contractor to avoid delay claims.

How to pay for commissioning?

•**In-house budget**—A specific budget can be set aside specifically for commissioning each project under the direct control of the owner. A percentage of 1.5 to 4 percent is a reasonable level for a typical project. This level of funding compares favorably with the normal level of change orders typically experienced on capital projects that can range from 5 to 13 percent. The efforts expended during commissioning should generate considerable reductions in change orders. This is especially **true if the integrated approach** is taken from the start of the **project design**.

• *lilcr'cpzncknbudget*—Another approach is to set up an indepen-

dent budget for commissioning that is totally separate from the project budget. This budget may be part of an owner's operating budget, which normally includes maintenance and other items. This line item budget approach is feasible in cases where an owner has an on-going construction program for which a consistent commissioning process must be maintained over many projects.

A typical 50,000 sq ft office building may require a budget of at least \$75,000 for HVAC system commissioning and \$150,000 for total building commissioning.

***Add to A&E fee**—This approach is attractive to the architectural/engineering firms because it **offers an** additional source of revenue and gives them the financial flexibility to look after the owner's interests as their designated agent. It frequently is hard to quantify the level of compensation that is adequate for a typical project.

The percentage approach can be considered, but generally the lump sum approach is preferred by the owner to minimize the cost exposure.

•**Include contractor costs**—By including the total costs of commissioning compliance in the base bid of the contractor, the **owner has** the advantage of receiving a competitive price for this portion of the work. The contractor actually puts in his bid price with an allowance to cover the costs of commissioning. He **may use an** in-house staff or opt to retain an outside consultant to oversee the work. The disadvantage is that often to get the low bid, a contractor may choose to short cut the commissioning efforts by keeping it a low cost item.

Budgeting for commissioning services—The owners must commit to budget and fund properly the commissioning services realizing that most, if not all, of the cost will be recovered by a significant reduction in change orders and claims. Owners need to recognize

there is a cost to commissioning services, regardless of who does it. In a typical 50,000 sq ft office building project with a \$5.0 million construction budget, the commissioning budget amounts to **only** 1.5 to 3.0 percent. This amount is a realistic and achievable goal for claims and change order reductions. There are various ways to budget these costs. Depending on the scope defined by the owner, a suggested estimate is shown in Table 10.

Summary

Building commissioning enhances a building's value to the owner. The building systems are more reliable, and they perform better. Building operators experience less down time due to less re-

TABLE 10—Budget for commissioning services.

Commissioningscope	Cost range
A Total building commissioning (Thermal envelope, roof system, mechanical, electrical, life safety, energy management systems)	1.5 to 3 percent
A HVAC and energy management system	2.5 to 5 percent
A Electrical and lighting system	1.0 to 2 percent

quired maintenance. Properly functioning building systems use less energy; the occupants are more productive in a healthier workplace; and the building lasts longer. The commissioning process, when **properly** designed and implemented, produces a higher quality building with reduced costs to all parties involved. Commissioning is a quality process that produces high performance buildings, HPAC

A tribute: This article is dedicated to Nancy Benner, executive director, Portland Energy Conservation, Inc. (PECI) who passed away in July 1997. She was a true visionary and a pioneer in transforming building commissioning into an accepted business-as-usual practice in the building industry.

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